soil INSTRUMENTS

Man 233

Smart In-Place Inclinometer (IPI)

User Manual

Soil Instruments Limited has an ongoing policy of design review and reserves the right to amend these specifications without notice.
Man233 - Smart In-Place Inclinometer (IPI) - MN0814 - Rev1.0.1

What's this manual about?

This manual tells you about the Smart In-Place Inclinometer (Smart IPI) and how to use it to take measurements of lateral displacement within a borehole.

Who does this apply to?

Installers, field engineers and technicians who need to measure lateral displacement within a borehole.

Welcome!

Thank you for choosing the Smart In-Place Inclinometer (IPI).

This manual has been written to help you utilise all of the functions of the Smart IPI. Please read this manual thoroughly before use to help avoid any problems and keep it handy when using the Smart IPI.

Smart In-Place Inclinometer (IPI)

A Smart In-Place Inclinometer (Smart IPI) system is used to remotely monitor lateral displacement within a borehole.

The Smart IPI has been designed to supersede traditional IPI systems; with advanced single cable technology and new mechanical design, the Smart IPI is seen as a new product rather than just an improvement to the old.

The Smart IPI System comprises in its most basic form a Data Acquisition system, a Sensor Interface Module (S.I.M), one Top Support Assembly, up to 39 Smart IPI Sensors and one Terminating Sensor.

Contained within the Smart IPI Sensor body is a PCB and two MEMS sensors. The data is transmitted via the single cable that runs from the bottom of the borehole at the Terminating Sensor, up to the top of the borehole through up to 39 standard sensors and the Top Support Assembly. This cable plugs into a Sensor Interface Module (S.I.M.) which is connected to a Datalogger, both housed together within an enclosure at the surface.

Each Smart IPI Sensor is connected to the next using an Easy-Connect Coupling, starting with a Terminating Sensor and culminating in a Top Support Assembly with an easily adjustable setting bar. A Top Support spans the pre-installed casing which holds the Smart IPI in place in a vertical borehole, or maintains its position in a horizontal borehole.

The Smart IPI incorporates a Support Wire System to aid with removal and to prevent loss or damage to the string of the Smart IPI Sensors, should the assembly slip or be accidentally dropped.

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Part I – Overview

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Introduction:
Important Information

The following symbols are used throughout the manual

IMPORTANT INFORMATION

QUESTION

WARNING

TIP

! Important: Failure to adhere to the warnings in this manual may result in network disruption and possible data loss.

Failure to observe the warning may result in injury, product malfunction, unexpected readings or damage to the product that may invalidate its warranty.

Tips give additional information that may be helpful when using the Smart In-Place Inclinometer (IPI) system.

PRODUCT CHANGES

Soil Instruments has an on-going policy of design review and reserves the right to amend the design of their product and this instruction manual without notice.

WARRANTY

Refer to our terms and conditions of sale for warranty information. The batteries are a consumable item and are excluded from the warranty.

DISPOSAL

Products marked with the symbol are subject to the following disposal rules in European countries:

- **This product is designated for separate collection at an appropriate collection point**
- **Do not dispose of as household waste**
- **For more information, contact Soil Instruments or the local authority in charge of waste management.**

System Description
Things You Need to Know About the Smart IPI System

FEATURES

- Biaxial MEMS Sensors
- Single cable system
- Sensor strings give a readily automated profile of vertical or horizontal displacements
- Factory allocated serial numbers
- Onsite allocation of Sensor IDs
- Mechanical and electrical connection rated IP68 to 2000 kPa
- Accurate and precise measurements using MEMS sensors

BENEFITS

- Easy to automate using data acquisition system and '**ARGUS**' monitoring software
- Removes the need for manual monitoring
- Fast onsite installation with minimal cable management
- Plug-and-play into Sensor Interface Module (S.I.M.)
- Calibration factor stored in each sensor allow output in engineering units
- Up to 40 Smart IPIs per borehole (including Terminating Sensor)
- Ability to add to the network as and when required

System Components

FOR EACH BOREHOLE YOU WILL NEED:

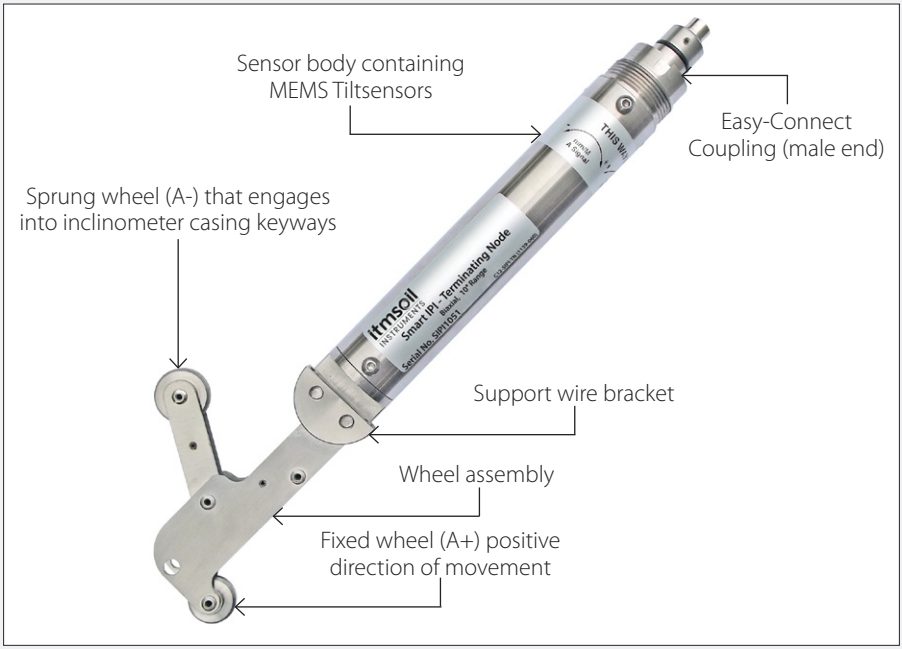
- 1 x Terminating Sensor
- Up to 39 x Smart IPI Sensors
- 1 x Top Support Assembly
- 1 x Steel support wire

PER 40 SMART IPI SENSORS YOU WILL NEED:

- 1 x Sensor Interface Module (S.I.M.) house in a Datalogger
- Either mains power with battery backup (preferred), or 12V battery plus Solar/wind charging battery pack

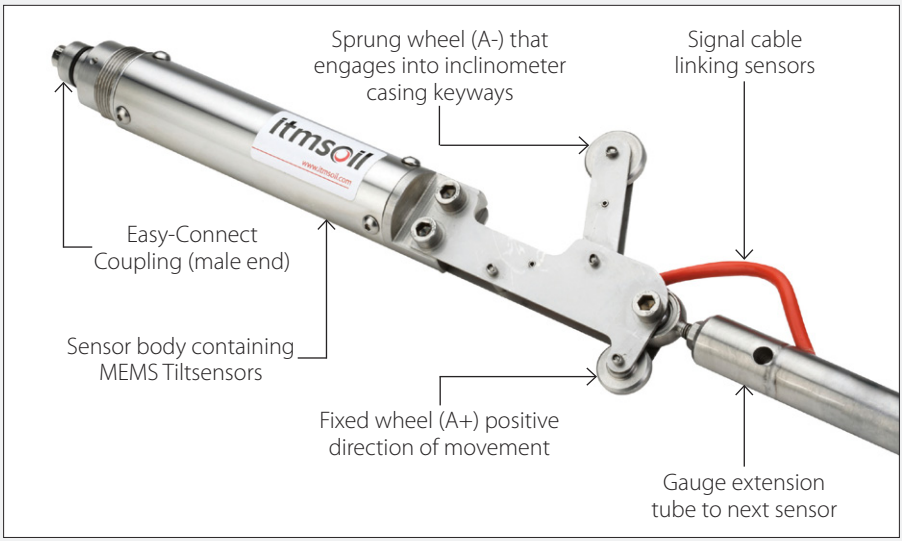
SMART IPI TERMINATING SENSOR

The components of the Terminating Sensor are identified below:



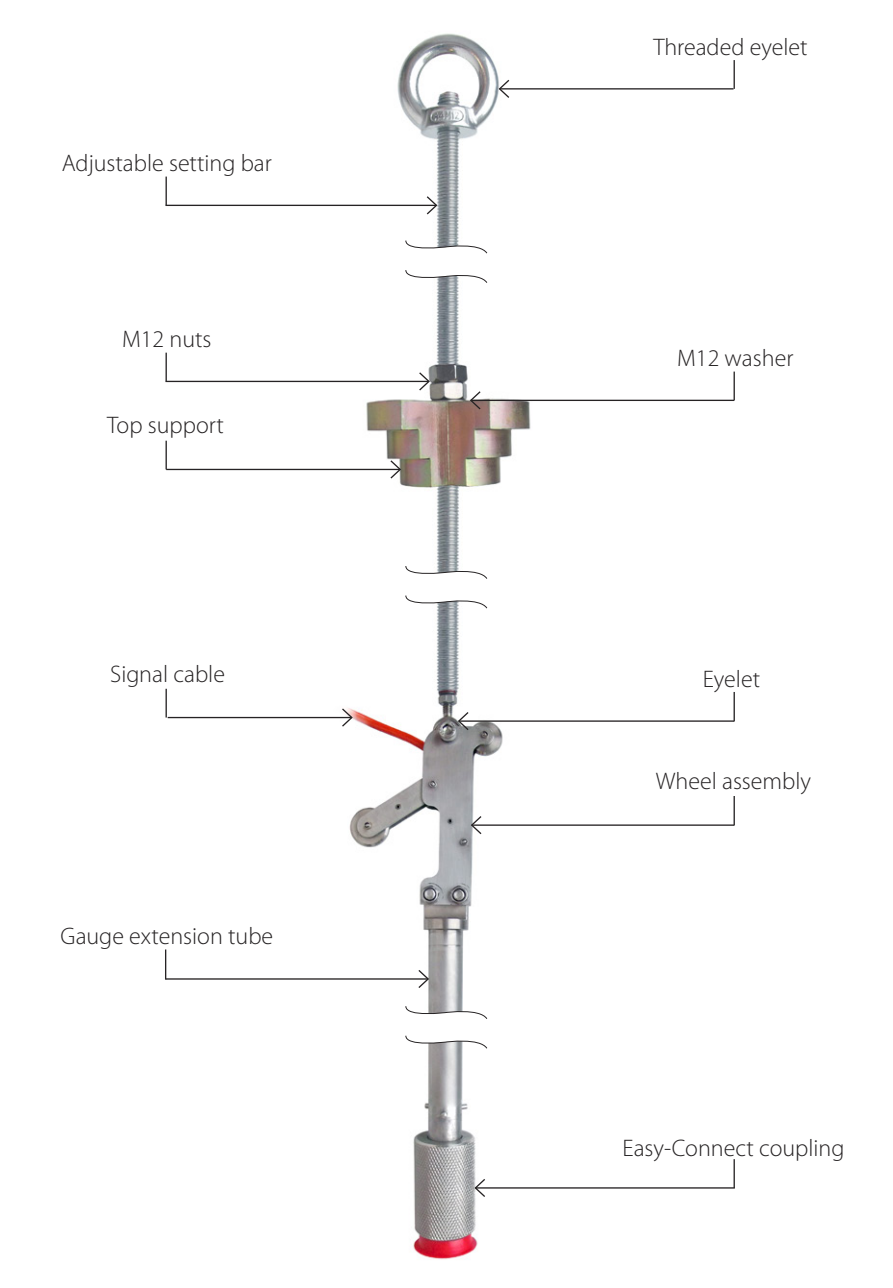
SMART IPI SENSOR

The components of the Smart IPI Sensor are identified below:



TOP SUPPORT ASSEMBLY

The components of the Top Support Assembly are identified below:



SENSOR INTERFACE MODULE (S.I.M.)

The Sensor Interface Module (S.I.M.) is identified below:

SMART IPI SYSTEM

A string of Smart IPIs, including the Terminating Sensor at the bottom and the Top Support Assembly at the top, is assembled on site and installed in a borehole.

Each Smart IPI contains a Smart Control PCB, which processes the MEMS sensor signal to provide output in engineering units.

The data is transmitted from each Sensor via a single CANbus to a Sensor Interface Module (S.I.M.) which is connected to a Datalogger, both housed within an enclosure located onsite. This combined system is used to power the Smart IPIs, configure and enumerate the Smart IPI network and transmit measurements from sensors, communicating data to the user.

The data can be directly imported into '**ARGUS**' monitoring software suite, a graphical user interface (GUI) that allows quick and easy data interpretation, enabling a fully automated system.

Quick Start Guide to Installing the Smart IPI System

Follow the instructions outlined in this manual at all times to ensure correct installation and maintenance of the Smart IPI System.

BEFORE YOU GO TO SITE:

Please follow the steps outlined below to ensure the correct installation of the Smart IPI System. Please also refer to ***Part II – Detailed Smart In-Place Inclinometer Installation Guide*** in this manual for more details.

STEP	ACTION
1	Lay out all the components of the Smart IPI System and check all parts are present and correct and have not been damaged in transit.

WHEN YOU ARE IN THE FIELD:

Soil Instruments recommend an **intermediate** skill level for installing a Smart IPI System.

STEP	ACTION
1	Lay out all the components of the Smart IPI System in the correct order of installation.
2	Determine the A+ (+mm) direction in which to install the Smart IPI Terminating Sensor; the fixed wheel facing towards the direction of movement and the sprung wheel away from the direction of movement.

Once you have determined the A+ direction for the Smart IPI Terminating Sensor, all other Smart IPIs will orient in the same direction when connected together.

3	Attach the support wire to the support wire bracket on the Terminating Sensor. Please refer to ***Part II – Detailed Smart In-Place Inclinometer Installation Guide - Attaching the Terminating Sensor and Steel Support Wire*** in this manual for more details.
4	Install the Sensor Interface Module (S.I.M.) and Datalogger within a reasonable distance from the top of the borehole.
5	Attach the Top Support to the Top Support Assembly.
6	Immediately before you lower the Smart IPI Sensor into the borehole, make a note on an installation sheet of its serial number, position in the string and depth. Repeat for all subsequent sensors.

If you are fitting the Smart IPIs into recently installed casing, you must take care to ensure that any hydration heat has dissipated before you install the Smart IPI Sensors.

Immediately before you lower each sensor into the borehole, make a note on an installation sheet of its serial number, position in the string and depth.

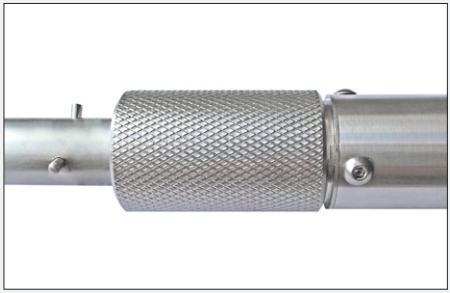
STEP	ACTION
7	Lower the Smart IPI Terminating Sensor into the borehole, supporting the gauge extension tube with the Installation Support Tool to prevent the sensor from falling down the borehole.
8	Attach the next Smart IPI Sensor using the Easy-Connect Coupling.
9	Repeat with subsequent sensors, keeping the steel support wire free from snagging.
10	Attach the Top Support Assembly to the top of the last Smart IPI Sensor using the Easy-Connect Coupling, adjusting and locking the position of the Top Support using the M12 nuts.
11	Using armoured cable, connect the cable from the string of Smart IPIs to the Sensor Interface Module (S.I.M) housed within the Datalogger enclosure.
12	Start logging.

Installing a string of Smart IPI Sensors without using a steel support wire can result in loss or damage of the string if the assembly slips or is dropped into the borehole accidentally.

Ensure the cable does not become snagged stretched or kinked. The same applies to the support wire.

Easy-Connect Coupling

Correctly Connected



Incorrectly Connected

Part II – Detailed Smart IPI Installation Guide

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Installing the Smart IPI

This manual assumes that you have already installed quality inclinometer casing. For details of suitable casing, please see Soil Instruments datasheets C9, C9-4 and C18.

If you are fitting the Smart IPIs into recently installed casing, you must take care to ensure that any hydration heat has dissipated before you install the Smart IPI Sensors.

TOOLS REQUIRED

- Length of 3mm steel support wire 5m longer than depth of borehole
- M12 spanner (for adjustment and tightening of the Top Support)
- M4 spanner (for adjustment and tightening of the support wire shackle clip)
- Flat ended terminal screw driver (wiring)
- Installation Support Tool

HOW TO INSTALL SMART IPIS

An installed string of sensors (five shown in the example below) will be installed in the following way:

(Bottom of borehole)

1. **Smart IPI Terminating Sensor;** wheel assembly with support wire bracket and support wire attached, Easy-Connect Coupling

▼

2. **Smart IPI Sensor;** wheel assembly, gauge extension tube, Easy-Connect Coupling

▼

3. **Smart IPI Sensor;** wheel assembly, gauge extension tube, Easy-Connect Coupling

▼

4. **Smart IPI Sensor;** wheel assembly, gauge extension tube, Easy-Connect Coupling

▼

5. **Smart IPI Sensor;** wheel assembly, gauge extension tube, Easy-Connect Coupling

▼

(Top of borehole)

Top Support Assembly; Easy-Connect Coupling, gauge extension tube, wheel assembly, adjustable setting bar, Top Support, eyelet, support wire, shackle clip, signal cable

▼

Armoured cable

▼

Sensor Interface Module (S.I.M)

▼

Datalogger

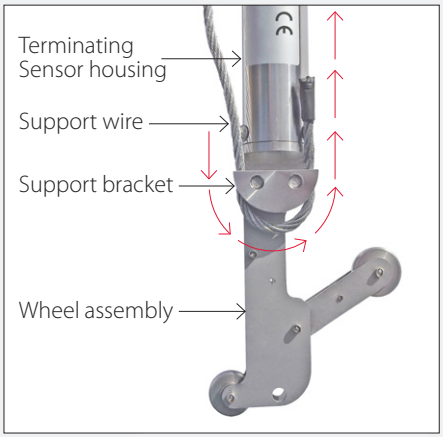
Installing a string of Smart IPI Sensors without using a steel support wire can result in loss or damage of the string if the assembly slips or is dropped into the borehole accidentally.

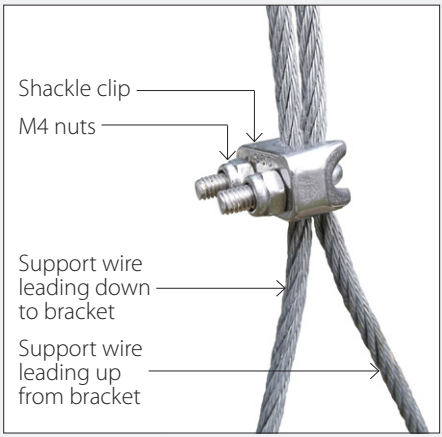
TERMINATING SENSOR AND SUPPORT WIRE

The Terminating Sensor can be easily identified as it does not have a gauge extension tube and has a support wire bracket attached to the wheel assembly for attaching the support wire.

Thread the support wire down through the first hole in the wire support bracket, loop around the underneath of the bracket and thread back up through the second hole. Feed the support wire through the bracket until there is a suitable length to attach to the full length of the support wire, ideally above the Terminating Sensor housing. Connect the free end of the support wire to the full length using the shackle clip provided. Once the support wire loop is adequately placed, tighten the M4 nuts securely with a spanner.

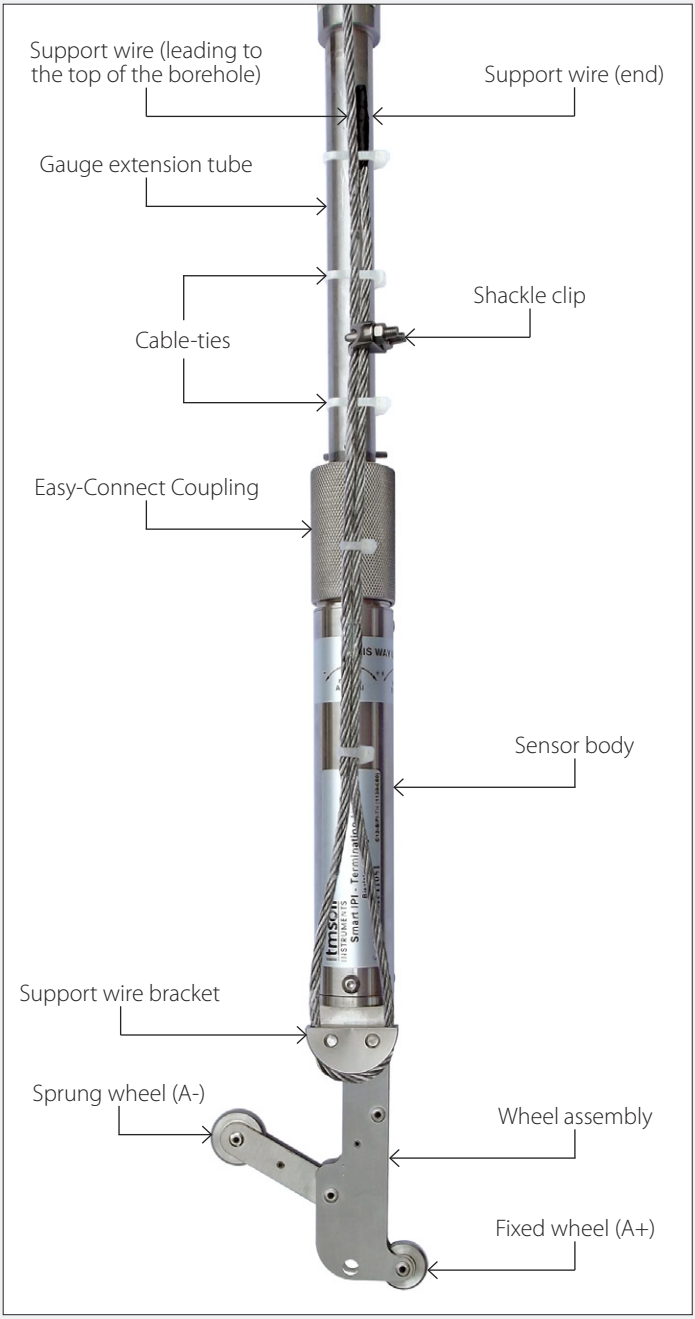
Leave a suitable length of the end support wire protruding from the shackle clip and ensure the M4 nuts on the shackle clip are securely tightened.





Tape or cable-tie the free end of the support wire to the gauge extension tube to prevent snagging.

Terminating Sensor with Gauge Extension Tube and Support Wire



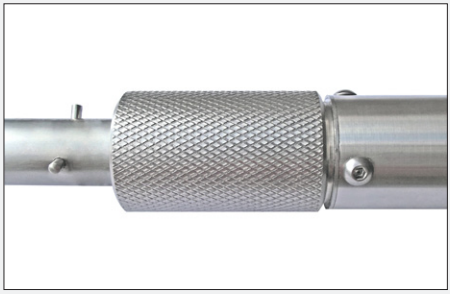
CONNECTING THE SENSORS

Push the Smart IPI connection into the Easy-Connect Coupling located on the end of the gauge extension tube, making sure to align the slot on the Smart IPI with the notch on the Easy-Connect Coupling, then securely tighten the threaded barrel.

Easy-Connect Coupling

Correctly Connected

Incorrectly Connected



Immediately before you lower each sensor into the borehole, make a note on an installation sheet of its serial number, position in the string and depth.

Please refer to *Part IV – Appendices - Appendix A - Installation Sheet Example* in this manual for more details.

CONNECTING & LOWERING THE FIRST SENSORS

Please follow the steps outlined below to ensure the correct installation of the Smart IPI System. Soil Instruments recommend an **intermediate** skill level for installing a Smart IPI System.

Join the Terminating Sensor to the first Smart IPI Sensor before you attempt to lower the sensors down the borehole.

STEP	ACTION
1	Locate the A+ (+mm) direction of the Terminating Sensor; the fixed wheel should be facing towards the direction of movement and the sprung wheel away from the direction of movement.
2	Pick up the second Smart IPI Sensor and align the slot on the sensor end with the notch on the gauge extension tube end. Gently push together and tighten using the threaded barrel. Both these sensors are connected before they are lowered into the borehole. Please refer to ***Part II - Detailed Smart IPI Installation Guide - Connecting the Sensors*** in this manual for more details.

Immediately before you lower each sensor into the borehole, make a note on an installation sheet of its serial number, position in the string and depth.

STEP	ACTION
3	Immediately before you lower the sensors into the borehole, make a note on the installation sheet of their serial numbers, position in the string and depth. Whilst holding the Terminating Sensor with one hand, gently guide the wheel assembly (bottom wheel first) into the borehole with the fixed wheel facing towards the A+ direction. Make sure that both wheels are correctly aligned in the keyways of the casing. Guide the wheel assembly of the second Smart IPI sensor into the borehole in the same manner as before and place the Installation Support Tool in the available slot directly underneath the second Smart IPI Sensor, just above the bolts where the sensor connects to the wheel assembly.

STEP	ACTION
3	The Installation Support Tool spans the inclinometer casing, preventing the sensor from falling into the borehole, allowing you to fit subsequent sensors with ease. The Smart IPI Sensor can now rest safely in place on the Installation Support Tool.

Take care to ensure that the wheels remain in the keyways of the casing and that they are not snagged by the support wire which should be free to move within the borehole.

CONNECTING & LOWERING SUBSEQUENT SENSORS

Pick up the next Smart IPI Sensor and align the slot on the sensor end with the notch on the gauge extension tube end. Gently push together and tighten using the threaded barrel as before, then raise to vertical and lower into the borehole, making sure that both wheels are correctly aligned in the keyways of the casing.

Repeat this process until all except the last (top) sensors are installed, remembering to note the serial number, string position and depth for each sensor as you go.

LAST SENSOR & TOP SUPPORT ASSEMBLY

The Top Support Assembly supports the Smart IPI string in a vertical borehole and maintains its position in a horizontal borehole.

STEP	ACTION
1	Attach the final gauge extension tube assembly to the last sensor using the Easy-Connect Coupling and tighten the threaded barrel.
2	Attach the adjustable setting bar to the wheel assembly using the eyelet on the gauge extension tube of the Top Support.
3	Measure the distance from the fixed wheel on the gauge extension tube of the Top Support Assembly to the required location for the Top Support (where it will rest within the top of the casing).
4	Place the Top Support over the adjustable setting bar, followed by the M10 washer and the M10 nut and thread down until you reach the previously measured distance.
5	Raise the Top Support Assembly into a vertical position, as before, and lower it into the borehole until the Top Support reaches the top of the casing.
6	Centralise the Top Support and place securely within the casing.
7	Make any final adjustments to the length of the IPI string if needed before securely tightening the M10 nut.

If the borehole is under depth, the top sensor may not fit fully into the borehole at the desired gauge length. If this happens, remove the last sensor and reposition the Top Support by moving it closer to the wheel assembly of the top sensor.

9	Thread a second M10 nut over the adjustable setting bar until it reaches the first nut. Lock off the second nut securely against the first.
10	Thread the eyelet onto the top of the adjustable setting bar and tighten until it is secure.
11	Thread the steel support wire through the eyelet ensuring there is sufficient length to securely fit the shackle clip.
12	Fit the shackle clip to the support wire in the same way as it was attached at the Terminating Sensor.

Top Support Assembly; eyelet with steel support wire and shackle clip

SENSOR INTERFACE MODULE (S.I.M)

The Sensor Interface Module (S.I.M.) is the link between the logger and the sensors within the borehole. The S.I.M. is housed with the Datalogger in an enclosure, which should be installed within a reasonable distance from the Smart IPI installation.

Please refer to ***Part III – Detailed Sensor Interface Module Guide*** in this manual for installation details.

Part III - Detailed Sensor Interface Module (S.I.M.) Guide

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Sensor Interface Module (S.I.M.)

OVERVIEW

The Sensor Interface Module (S.I.M.) unit is the link between the Datalogger and the sensors within the borehole. The S.I.M. responds to commands sent to it by the logger in a question and answer format, processes the commands and then responds appropriately. The S.I.M. also monitors temperature and the voltage and current supply to the string of sensors, protecting them when necessary.

STATUS LEDS

On the front of the Sensor Interface Module (S.I.M.) are three LEDs to indicate the current status of the module; these are explained in the table below.

NAME	COLOUR	STATE	DESCRIPTION
Status	Green	Constant off	The module either has no power
		Slow blink	The module is currently idle
		Fast blink	The module is currently active
Sensor power	Green	Constant off	Power to the sensor network is off
		Constant on	Power to the sensor network is on
		Blinking	Sensor string Current warning level (3Amp)
Fault	Red	Constant off	No fault
		Constant on	A fault has occurred
		Blinking	Current limit reached (4Amp), system lockout, must remove the load and reset the system

CONNECTING THE SMART IPI STRING TO THE (S.I.M.)

The Sensor Interface Module (S.I.M) is housed with the datalogger in an enclosure, which has been previously installed within a reasonable distance from the Smart IPI installation. The cable from the sensor string is wired into the terminals in the S.I.M.

Please refer to ***Part IV – Appendices – Appendix B - Datalogger Wiring Diagram*** in this manual for more details.

LOGGER CONTROL

When used in conjunction with a Datalogger, the Sensor Interface Module (S.I.M.) will instruct the logger to automatically collect sensor information, which is then used by the logger to setup a data table linked to the sensors serial number.

The logger will request a read cycle and the S.I.M. will broadcast a message via the CANbus, requesting the sensors to return a measurement in succession.

When the sensor returns data, it is passed on by the S.I.M. via the RS232 port to the Datalogger.

Some sensor parameters can be adjusted in the logger if required, such as changing the samples requested and filtering.

S.I.M. WIRING CODE

SMART IPI SENSOR	
Red (+)	Vcc [11-16]
Black	Ground
Green	Can High
White	Can Low
Shield	Shield

POWER SUPPLY	
Red (+)	Vcc
Black	Ground
Shield	Earth

POWER REQUIREMENTS

TYPE	
Battery	11-16VDC
Mains; maximum current draw with sensors active	4 Amps; maximum supplied per string
Sensor; standby	25mA maximum

Part IV – Appendices

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This section contains the following topics.

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Appendix A - Installation Sheet Example

Document Title	Smart In-Place Inclinometer (IPI) Installation Record Sheet		
Date: 31/10/2013	**Installer:** John Smith	**Site:** Site Identifier	**Borehole ID:** BH01
Borehole Depth: 26m	**No. of Sensors:** 25	**A+ Direction:** North	**Casing Size:** 70mm

Sensor Depth	Sensor Position	Serial Number	Gauge Length
25m	25: Terminating Node	41226	1m
24m	24	41227	1m
23m	23	41228	1m
22m	22	41229	1m
21m	21	41230	1m
20m	20	41231	1m
19m	19	41232	1m
18m	18	41233	1m
17m	17	41234	1m
16m	16	41235	1m
15m	15	41236	1m
14m	14	41237	1m
13m	13	41238	1m
12m	12	41239	1m
11m	11	41240	1m
10m	10	41241	1m
09m	09	41242	1m
08m	08	41243	1m
07m	07	41244	1m
06m	06	41245	1m
05m	05	41246	1m
04m	04	41247	1m
03m	03	41248	1m
02m	02	41249	1m
01m	01	41250	1m

NOTES:
A+ direction towards excavation, IPIs installed to depth (25m).
Installation assisted by Alan Jones, installation records completed by John Smith.
No issues occurred during installation.

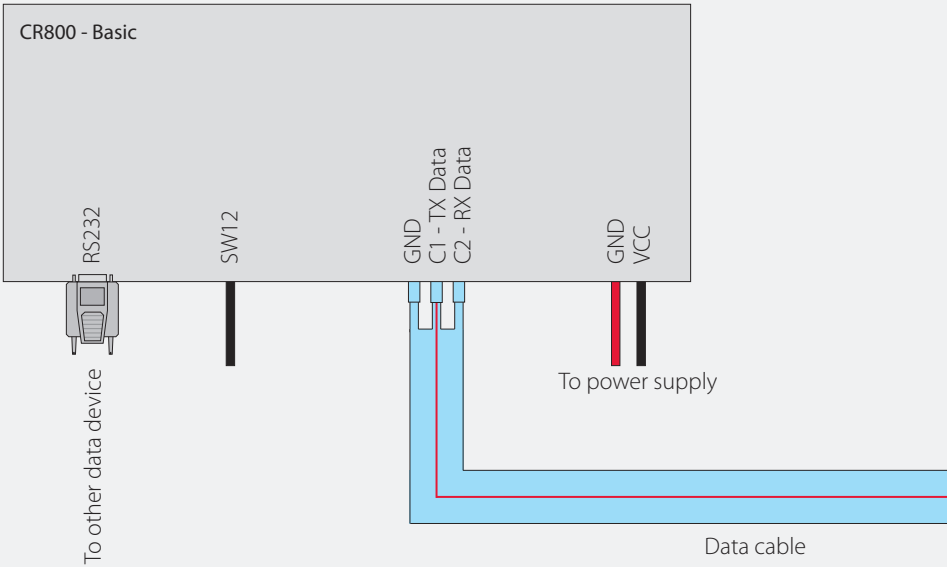
Blank Installation Sheet

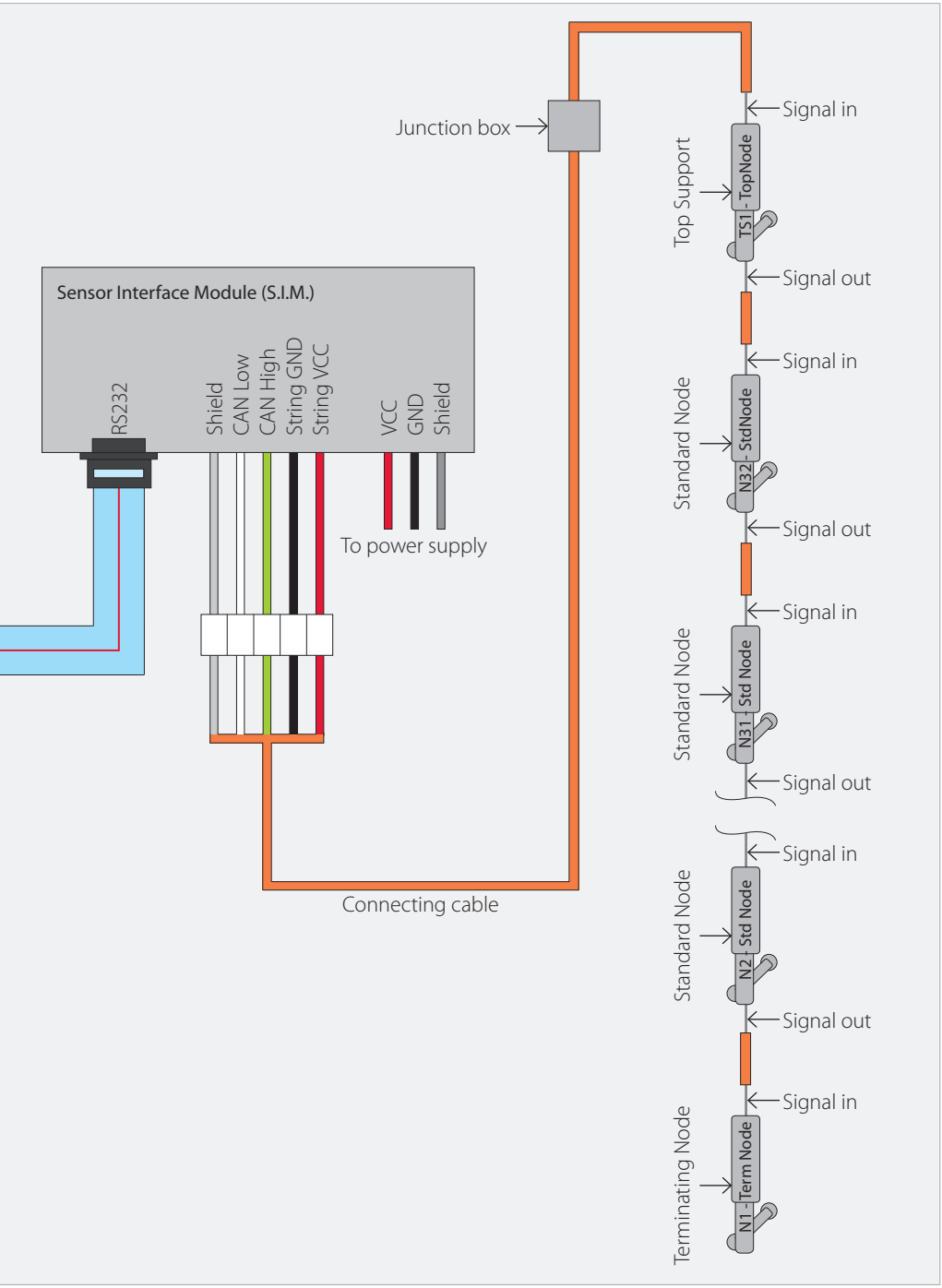
Document Title	Smart In-Place Inclinometer (IPI) Installation Record Sheet		
Date:	Installer:	Site:	Borehole ID:
Borehole Depth:	No. of Sensors:	A+ Direction:	Casing Size:

Sensor Depth	Sensor Position	Serial Number	Gauge Length

NOTES:

Appendix B - Datalogger Wiring Diagram




Sensor Interface Module (S.I.M.)
RS232
Shield
CAN Low
CAN High
String GND
String VCC
VCC
GND
Shield
To power supply
Junction box
Connecting cable
Top Support
TS1 - TopNode
Standard Node
N32 - StdNode
Standard Node
N31 - Std Node
Standard Node
N2 - Std Node
Terminating Node
N1 - Term Node
Signal in
Signal out
Signal in
Signal out
Signal in
Signal out
Signal in
Signal out
Signal in

SUPPORT

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